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SAFETY OF CONVENTIONAL FUEL PUMPS AND FUEL LEVEL INDICATORS IN FUEL TANKS OF ROAD VEHICLES USING ALCOHOL FUELS

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ABSTRACT

In 1986, the Road Safety Directorate of Transport Canada contracted Celanese Canada Inc. to perform a study of the safety aspects of Alcohol Fuels in Road Vehicles (1). This study included such things as autoignition temperature, limits of flammability, flame luminosity, miscibility with water, analysis of headscape vapours, incidents of fires and firefighting considerations.

The contractor was unable to perform one important study, the safety of in-tank fuel pumps and fuel level gauges in the presence of alcohol fuels, so the Canadian Explosive Atmospheres Laboratory were asked to undertake this study.

The headspace of a fuel tank containing gasoline contains a saturated mixture of vapour and air which is above the upper limit of flammability down to approximately -40°C. Therefore, a spark in the fuel tank caused by a faulty electrical component is not likely to cause an explosion. Methanol, on the other hand, will produce an ignitable vapour, in its saturated state, at approximately 11°C. Mixtures of methanol and gasoline were found to have "flash points" somewhere between these two figures.

KEYWORDS: Methanol fuels, alcohol, fuel pumps, road vehicles, intrinsic safety.

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ABSTRACT (Cont'd)

In this study, several different fuels and three electrical devices normally found in fuel tanks of gasoline powered automobiles were tested to determine the safety of these devices in automobiles powered by methanol and methanol/gasoline blends. This is Phase II of the Transport Canada study and is supplementary to the report on Phase I by Celanese Canada Inc. (1).

SÉCURITÉ DES POMPES D'ALIMENTATION EN CARBURANT ET DES INDICATEURS CLASSIQUES DE NIVEAU DE CARBURANT DANS LES RÉSERVOIRS DES VÉHICLES ROUTIERS ALIMENTÉS AVEC DES CARBURANTS ALCOOLISÉS

J.A. Bossert* et E. Dainty**

RÉSUMÉ

En 1986, la Direction de la sécurité routière de Transports Canada a passé un contrat avec la Celanese Canada Inc. pour faire faire une étude des aspects relatifs à la sécurité des carburants alcoolisés dans les véhicules routiers (1). Cette étude portrait entre autres sur la température d'autoallumage, les limites d'inflammabilité, la luminosité de la flamme, la miscibillité avec l'eau, l'analyse des vapeurs présentes dans l'espace libre du réservoir, les incendies et des considérations relatives à la lutte contre les incendies.

L'entreprise n'a pu effectuer une importante partie de l'étude, soit celle qui devait porter sur la sécurité des pompes d'alimentation et des indicateurs de niveau de carburant incorporés dans le réservoir, en présence de carburants alcoolisés. C'est pourquoi on a demandé au Laboratoire canadien de recherche sur les atmosphères explosives d'entreprendre ce travail.

L'espace libre d'un réservoir d'essence renferme un mélange saturé de vapeur et d'air dont la concentration se situe au-dessus de la limite supérieure d'inflammabilité jusqu'à environ -40°C. Il est donc peu probable qu'une étincelle se produisant dans le réservoir à cause d'une

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MOTS CLÉS: combustible méthylique, alcool, pompes d'alimentation, véhicules routiers, sécurité intrinsèque.

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RÉSUMÉ (Suite)

composante électrique défectueuse provoque une explosion. Par contre, le méthanol dégagera une vapeur qui, à la concentration de saturation, s'enflammera à environ 11°C. On a constaté que les "points d'éclair" des mélanges de méthanol et d'essence se situaient entre ces deux températures.

Dans la présente étude, on a testé plusieurs carburants différents et trois dispositifs électriques qu'on trouve normalement dans les réservoirs des automobiles alimentées à l'essence, pour déterminer si ces dispositifs étaient sécuritaires dans les automobiles alimentées avec du méthanol et avec des mélanges de méthanol et d'essence. Ces travaux constituent la II^{e} phase de l'étude effectuée par Transports Canada et ils complètent le rapport de la I^{e} phase de l'étude réalisée par la Celanese Inc. (1).

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INTRODUCTION

In Phase I of this study, eleven fuels were studied. These are shown in Table 1.

TABLE 1

Fuel No.	Nominal Composition (% by volume)
1	Methanol, commercial grade
1a	Methanol, commercial grade with Cetane Improver
2	Summer grade Gasoline
3	Winter grade Gasoline
4	4.7% Methanol/4.7% Isobutanol/90.6% WG Gasoline
5	10% Ethanol/90% SG Gasoline
6	10% Ethanol/90% WG Gasoline
7	90% Methanol/10% SG Gasoline
8	85% Methanol/15% WG Gasoline
9	85% Methanol/13% WG Gasoline/2% Butane
10	85% Methanol/10% WG Gasoline/5% Dimethylether

After reviewing the properties of these fuels, it was decided that for the Phase II study it would only be necessary to test Fuel Nos. 1 (methanol), 1a (methanol with cetane improver), 2 (gasoline), 8 (85% methanol/15% gasoline) and 9 (85% methanol/13% gasoline and 2% butane).

The first task was to test these fuels at different temperatures using a standard apparatus and a standard circuit to determine the most easily ignited fuel and the temperature at which that fuel was most easily ignited. For this purpose, the spark test apparatus described in the International Electrotechnical Commission (IEC) Recommendation 79-3 (2) was used. Canada is a member of IEC and an active participant in the work of the technical committee which produced this document. In addition, the Canadian National Standard on Intrinsic Safety, Canadian Standards Association C22.2 No. 157 (3) specifies this same apparatus and it has been adopted by most of the industrialized countries of the world.

The standard calibration circuit for this apparatus is 24v DC, 95 millihenries (mH). The resistance of the circuit is varied to control the current so that the sensitivity of a gas or vapour is normally expressed as the minimum current which will cause ignition. For example, hydrogen is considered to be the most sensitive having a minimum ignition current (using the above circuit) of 30 Ma. Methane is at the other extreme, having a minimum ignition current of 110 Ma.

After determining the fuel having the lowest ignition current and the temperature at which the ignition current was lowest (in the saturated state) the next task was to determine whether typical electrical fuel tank components presented any danger of igniting the vapour space in the tank under normal or fault conditions. For this study, two fuel pumps and a fuel gauge were operated under normal and abnormal conditions using a 12 v rechargeable battery connected to a power supply which kept it fully charged at all times. The circuit supplying those components was made and broken in the spark test apparatus in the presence of the vapour of the most sensitive fuel/air mixture.

METHOD

The spark test apparatus is normally operated at room temperature using the most easily ignited fuel/air mixtures which are specially prepared in a separate device. In this case, in order to simulate actual operating conditions, it was decided to simulate an "empty tank" situation by injecting a small volume of liquid fuel into the "dome" of the apparatus (see Figure 1). The volume injected represented approximately 1/30th of the total volume of the dome. Before this was done, both the fuel and the apparatus were placed in a temperature chamber until they had stabilized at the actual test temperature. After injecting the fuel, the apparatus was operated, without any current passing through the electrodes, (to give a mixing action) for 40 minutes to ensure that the mixture was saturated.

The apparatus was then connected to the standard calibration circuit of 24v, 95mH and the current was raised by steps of 10 mA (starting at 100 mA) until ignition occured. At least 320 revolutions of the electrode holder (representing over 1280 sparks) were performed at each current in accordance with the IEC standard operating procedure. Only after three consecutive trials gave similar results was the point considered for the ignition curve.

After the ignition curves were established, the three electrical devices were tested using the same procedure as above using the fuel and temperature found to be the most easily ignited. However, the actual device and the 12V battery were used for the circuit instead of the standard calibration circuit.

DISCUSSION OF RESULTS

The results of the fuel study are shown in Figure 2. From these curves, fuel No. 8 was selected for the tests on the electrical devices. This fuel was not only one of those most easily ignited but it was also the most likely fuel to be used because fuels Nos. 1 and 1a (the other fuel having a low ignition current) are virtually pure methanol which was judged from Phase I of this study to have an unacceptably low luminosity.

It is interesting to note here that although gasoline is normally shown as having a "flash point" of -40°C and Methanol is normally shown as having a "flash point" of 11°C, the results show that ignition of the vapours is possible at -30°C and 25°C respectively. The reason for this is probably that "flash points" are performed using a different method and the chamber is not sealed as in the case of the standard IEC spark test apparatus. However, the "explosive limits" as determined in Phase I of this study (1) for methane are almost the same as those shown in Figure 2. (No determination was performed on gasoline in Phase I).

The fuel gauge and sending unit tested were Chrysler part Nos. 4375010 (gauge) and 4051663 (sending unit). These were connected as

shown in Figure 3 with the battery charged to 14.5v. The gauge drew approximately 228 mA under the most adverse condition. Fuel No. 8 was used and the apparatus was operated at a temperature of 22°C. There were no ignitions at 14.5v DC so the voltage was increased to 20v DC and later to 24v DC and still no ignitions occured. Immediately after this test, the standard calibration circuit was connected to the apparatus to check the calibration and the mixture ignited at 110 mA.

The first fuel pump tested was an AC 1-EP209, taken from a Pontiac Bonneville. The pump drew a current of approximately 3 A no load and about double that amount when pumping water. As this current is considerably above the limit for the standard spark test apparatus, (which is rated at 2 A maximum) a slight modification was required to test this pump. No. 24 AWG copper wires were substituted for the tungsten wires in the rotating electrode holder. This modification is recognized in the CSA Standard (3) for currents in excess of 2 A. The fuel pump was connected as shown in Figure 4 with the battery charged to 14.5v DC. Ignition of the fuel vapour occurred immediately.

In DC circuits where inductance is a problem, a common way of suppressing inductive sparking is to connect a diode across the inductive coil in such a direction that the diode does not conduct during normal operation, but short circuits the back EMF produced by the coil when the circuit is broken. An attempt was made to suppress the sparking of this fuel pump by connecting a diode across its terminals as shown in Figure 5. When the above test was repeated using the diode, there was no ignition of the fuel vapour.

The second fuel pump was a Chrysler "Turbo" No. 4203941-19224. This was a much larger unit than the AC pump and it drew about twice the current. The results were essentially the same as the first pump including the suppression of the sparks using a diode across the terminals.

CONCLUSIONS

1. A typical fuel level gauge appears to provide no hazard in any of the fuel mixtures tested.

2. Both of the fuel pumps tested could easily cause an explosion in a fuel tank containing an 85/15 blend of methanol/gasoline at a temperature of -22.5°C if there were a loose connection at the pump terminals.

3. Both of the fuel pumps tested could easily be safeguarded by installing diodes across the terminals as shown in Figure 5. According to intrinsic safety principles, two such diodes, independently connected should be used to ensure safety. Such a modification would add only a few cents to the cost of this component.

4. The ignition range of the 85/15 Methanol/Gasoline fuel chosen as the test fuel (-10 to -30°C) is well within the normal temperature range of Canadian winters. Although no tests were made at these limits, the ease of ignition for the fuel pumps suggests that they could probably ignite the vapour space for a considerable portion of this range.

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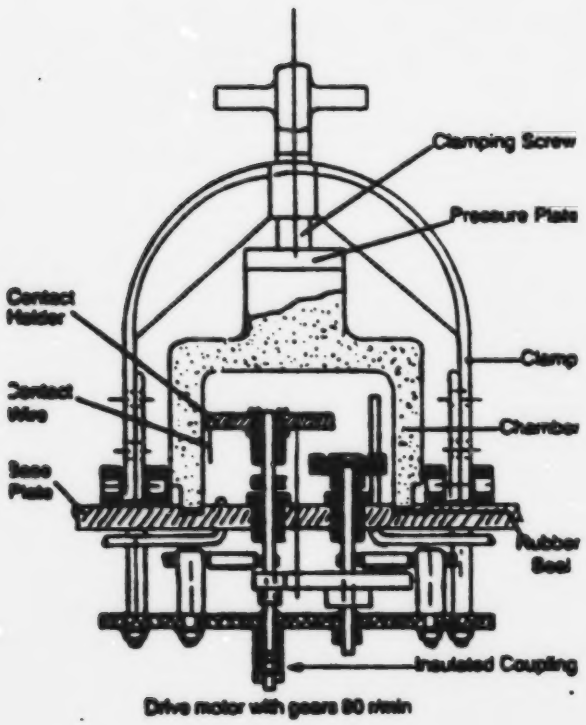

FIGURE 1

SPARK TEST APPARATUS

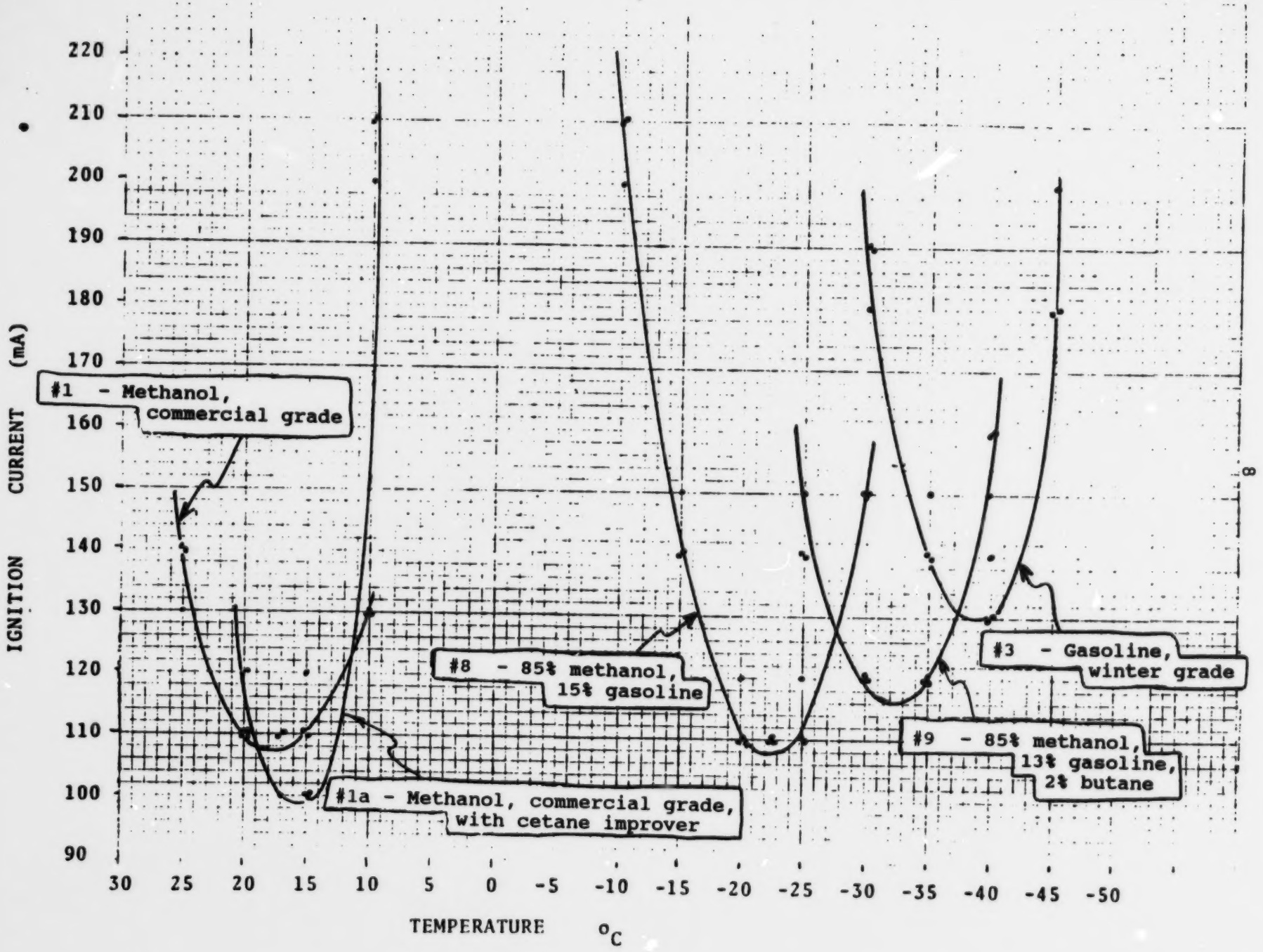
IGNITION CURRENT (mA)
220
210
200
190
180
170
160
150
140
130
120
110
100
90
#1 - Methanol, commercial grade
#8 - 85% methanol, 15% gasoline
#3 - Gasoline, winter grade
#9 - 85% methanol, 13% gasoline, 2% butane
#1a - Methanol, commercial grade, with cetane improver
30 25 20 15 10 5 0 -5 -10 -15 -20 -25 -30 -35 -40 -45 -50
TEMPERATURE °C

Figure 2

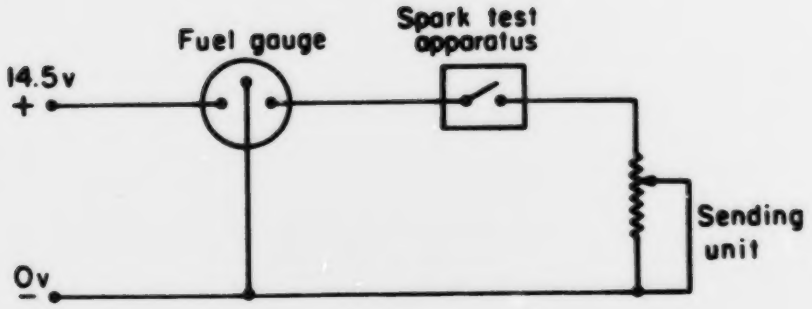

Figure 3 - Circuit for testing fuel gauge.

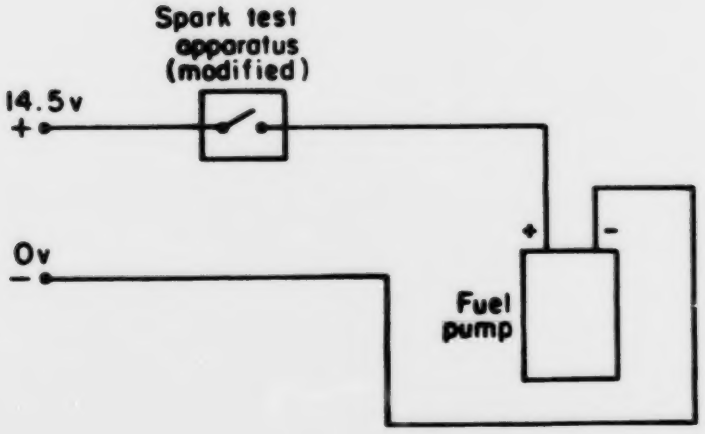

Figure 4 - Circuit for testing fuel pumps.

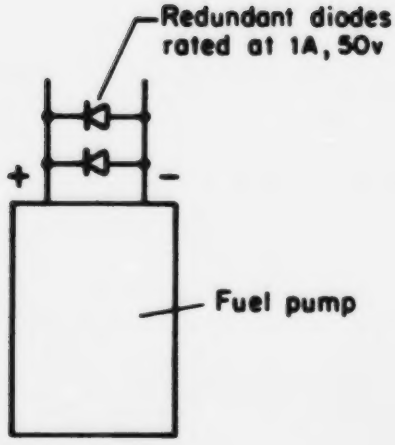

Figure 5 - Diode protection of fuel pump terminals.